A Taxonomic Framework for Formulating Strategies in Green Supply Chain Management

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Abstract

This paper addresses the increasingly important question of formulating appropriate strategies for green supply chain management. Due to increasing attention to green strategies and their impact on the natural environment, the development of a taxonomic framework for selecting appropriate strategies is imperative. In this study, we develop a taxonomic framework for formulating strategies for green supply chains based on characteristic green supply chain dimensions. The practical implication of this work is that the choice of green supply chain strategy impacts environmental and operations performance. The framework developed can be used as a tool for developing green supply chain management strategies, providing sound managerial insights.

Keywords
Green supply chain management; green strategies; environmental performance

1. Introduction
Due to ever-growing global economy and high levels of industrialization, environmental management has become a topic of mutual concern for businesses, government and consumers (Roberts, 2009; Plambeck, 2007; New et al., 2002; Azzone and Bertelè, 1994; Azzone and Noci, 1996; Azzone and Manzini, 1994). The growing concern in the global market for "green" issues and the scarcity of natural resources have forced executives to view supply chain strategies from an environmental perspective. In most high environmental risk industries (chemicals and plastics, automotive, heavy engineering, etc.), decision makers consider improvements in environmental performance as one of the basic competitive priorities, alongside lower costs, manufacturing lead time, or quality (Azzone and Noci, 1998). The European Union passed the Restriction of Hazardous Substance (RoHS) and the Waste Electrical and Electronic Equipment (WEEE) regulations demanding compliance with the relevant product recycling laws and prohibiting the use of hazardous substances in products for sale in the market.

Green supply chain management (GSCM) is mainly driven by the increased environmental deterioration such as overflowing waste landfills, depletion of raw materials, and pollution in general. A green supply chain primarily seeks to minimise the wastes within the industrial system so as to conserve energy, to prevent the dissipation of harmful materials into the environment. However, the main objective is not about environmental friendliness, but about a good sense of business and higher profits; it is a business value driver and not a cost centre (Wilkerson, 2005). Business organisations have realised the need to upgrade their supply chain management from a purely functional role to a more strategic role so as to comply with current environmental legislations and maintain an enduring competitive advantage (Shang and Marlow, 2005).

In earlier environmental management systems, operations managers were involved only at arm's length where individual organizational units managed environmental performance in product and process design, logistics, marketing, compliance regulations, and waste management. Whereas it has long been realised that green strategies should meet the required order winning criteria in the market place, the same idea needs to be extended to the entire supply chain. It has become crystal clear that best practices call for careful integration of environmental performance with operational performance in a collaborative climate. There is a growing need for integrating environmentally sound choices into supply chain management practice and research. Thus, research in supply chain management has recently shifted its focus to the role of the supply chain in;

(1) the natural environment
(2) improving environmental performance
(3) enhancing integrative collaboration

The paradigm shift has been influenced greatly by local and international legislative changes, market pressure, and the increased use of environmental requirements from customers in the supply chain. This has generally encouraged fast acceptance of green principles world-wide. Currently, there is a substantial need for improvement on the best way to select the most appropriate green strategy in a particular industry situation. Only a few researchers have considered the issue of identifying taxonomies for supply chain management. Research on taxonomy provides the basis for developing theories and testing hypotheses. Taxonomy also provides parsimonious categorical types without losing the main information or characteristics that exist within the type, and has been applied in strategic management and logistics studies (Shang and Sun, 2004). The aim of the present study is to develop a taxonomic framework for guiding decision makers when developing green strategies for specific industry set ups. In particular, the objectives of this study are:

(i) to investigate crucial GSCM dimensions based on a survey of extant case studies in literature
(ii) to develop a taxonomic framework to guide the selection of green strategies in supply chain management
(iii) to provide some managerial insights on the implications of the framework.

The next section presents the research methodology used in this work. A literature search survey is given in Section 3. Section 4 identifies the dimensions of GSCM that influence the choice of green strategies. A taxonomic framework for selecting green supply chain strategies is proposed in section 5. Section 6 presents concluding remarks for this study.

2. Research Methodology

The first and most crucial task of this research was to carry out a survey of real-world case studies in literature on GSCM and their implementation. Cases were chosen from published work in reputable journals that are concerned with GSCM studies. The second task was to highlight the main green strategic focus of each case study. The aim was to determine the major driving elements behind the choice and the final implementation of specific green strategies. This would answer managerial questions as to why certain strategies were chosen in specific industrial contexts. Therefore, the third task was to highlight those elements or dimensions that affected the selection and implementation of suitable green strategies. The analysis of the contexts in which specific strategies were chosen provides foundational building blocks for the development of a taxonomic framework to guide decision makers in selecting appropriate green strategies, given specific industrial situations. The fourth and final task was to develop a taxonomic framework for selecting or developing appropriate GSCM strategies. In the next section, the outcome of the literature search survey on real-world case studies on green supply chain is outlined.

3. Literature Search Survey

Literature search survey indicates that a number of organisations have embarked on introducing greening principles such as green procurement, green processes, green distribution, recycling and remanufacturing. Wal-Mart adopted green procurement of biodegradable or recyclable packaging. Automotive companies such as Toyota and Ford require ISO 14000 certification for their suppliers. A number of firms have invested in recycling and reuse, for instance, Dell, Hewlett Packard, Toshiba and other electronics industries (Hu and Hsu, 2006). In Western Europe, there is an obligation for 100% collection on “white goods” (Vlachos, 2007). The general acceptance of green activities has led to increasing empirical studies on the external and internal factors leading to the uptake of green practices and their impact on organisational performance (Simpson and Samson, 2008). Some patterns can be observed from these empirical case investigations. These studies can be categorised into four main areas of focus as shown in Table 1.

Table 1: An analysis of case studies in GSCM and their areas of focus

No.	*Description of area of focus of case study*	*Authors/References*
1.	Use of performance standards prescribing basic environmental requirements across the supply chain	Plambeck (2007); King et al. (2005); Melnyk et al. (2003).
2.	Integrating operational efficiency and waste reduction in line with supply chain objectives	Yan and Xia (2011); Corbett and Klassen (2006); Plambeck (2007).
3.	Use of environmental friendly technologies and innovations and their transfer across the supply chain	Klassen and Vachon (2003); Ninlawan et al. (2010); Lamming (1989); Heying and Sanzero, 2009; Roberts, 2009.
4.	Supply chain collaboration and development of remanufacturing and recycling systems	Hu and Hsu (2006); Pohlen et al. (1992); Stock (1998); Tibben (2002); Guide et al.(2003); Barros et al. (1998); Kumar and Yamaoka (2007); Pagell et al. (2007).

From these empirical research activities, it can be seen that the areas of concern for green supply chains are different from those of traditional supply chains (Beamon, 1999). Traditional supply chain performance is concerned with;

(i) Customer satisfaction, service quality, or responsiveness; or
(ii) Supply chain cost.

Contrary to traditional supply chains, green supply chains are typically focused on areas of their operations that influence environmental performance. These are categorised as follows:

(i) Waste (of all types);
(ii) Energy usage; and
(iii) Resource usage or material consumption.

It can also be seen from the above research activities that green supply chains tend to improve their performance by developing specific green capabilities and by building a supply chain relationship. According to Modi and Mabert (Kumar and Yamaoka, 2007), supply chain improvement towards the green practices is enhanced through competitive pressure from the market or customers, regulatory certification schemes, incentives, and direct involvement. Supply chain relationships are often developed based on two different climates, namely, (a) coercive climate, where contractual clauses are enforced between suppliers and customers (Zhu and Sarkis, 2007), and (b) collaborative climate, which calls for increased mutual involvement for customers and suppliers (Liker and Choi, 2004; Paulraj et al., 2008]. These climates act as determinants of the success of green strategies chosen. Because the coercive approach demands a prescribed minimal level of compliance to standards, it lacks capacity to encourage advanced performance management. On the other hand, collaboration encourages new knowledge, technologies and innovation. However, a higher level of inter-organisation involvement and collaboration is required, if green supply chain goals are to be achieved (Christopher, 2000). In this regard, we draw on the influence of supply chain collaboration on the success of GSCM strategies to define a framework for selecting appropriate green strategies. But how does the nature of process or product influence the success of the green supply chain?

Fisher (1997) presented examples from a diverse range of consumer products such as food, fashion apparel and automobiles, demonstrating why different supply chain strategies were required depending on whether products were functional or innovative. Functional products tend to have stable demand with long lifecycle (Christopher and Towill, 2002]. Since the characteristics of products have a direct influence on the choice of production process, their production systems tend to be functional as well. On the other hand, innovative products generally have unpredictable demand with short lifecycles. Consequently, their production processes are often innovative in nature. Therefore, product/process characteristics have a great influence on the choice of supply chain strategies. As in conventional supply chain management, the choice of green strategies in GSCM is directly affected by product characteristics. The success of GSCM goals, that is, waste reduction, minimal energy usage and optimal resource consumption, are strongly dependent on the green operations or processes chosen. In turn, the green operations are directly influenced by product characteristics.

From the above literature search survey, a question arises as to what might be the most appropriate green supply chain strategy for a particular product/process, or industrial relationship. What are the underlying dimensions of GSCM that influence the choice of green strategies? In this study we draw on the critical issues of supply chain relationship, product and process types to establish a taxonomic methodology for the selection of appropriate green supply chain strategies. The next section identifies relevant dimension and gradations of GSCM. A taxonomic framework for developing green supply chain strategies is presented in Section 5. Managerial insights and impacts of green strategies are given in section 6. Section 7 provides some concluding remarks.

4. Dimensions of Green Supply Chains

A few classification schemes have been proposed in literature, to guide the proper selection of conventional supply chain strategies (Christopher et al., 2006; Childerhouse, 2002). In this work, we realise that supply chain relationship has a direct impact on the choice of appropriate green supply chain strategies. Therefore, relationship is a crucial dimension that should be included in designing a taxonomic framework for the selection of appropriate green strategies. We suggest a three dimensional taxonomic scheme appropriate for GSCM. The dimensions and their gradations are outlined as follows:

(1) Relationship (industrial context) - is either coercive, or collaborative;
(2) Process - focuses on either eco-efficiency, or green efficiency;
(3) Product – is either functional, or innovative.

A coercive supply chain relationship is characterised by enforced contractual clauses between suppliers and customers. This approach demands a minimal level of compliance to standards, with very low information sharing. Suppliers seek to meet predictable demand at the lowest possible costs. Conversely, a collaborative supply chain calls for enhanced mutual involvement between customers and suppliers. In addition, supply chains tend to respond quickly to unpredictable demand due to their high agility and flexibility. Product life cycle costs and overall supply chain costs are the main objectives of the collaborative supply chain. This approach is conducive to innovation and dynamic technology evolution. Table 2 gives a summary of our views on coercive and collaborative supply chains

Table 2: An analysis of coercive versus collaborative supply chain relationships

Characteristic	*coercive*	*collaborative*
Information exchange	low information sharing	high information sharing
Market responsiveness	supply at lowest possible cost	respond quickly to dynamic demand
Supplier selection approach	consider cost and quality	consider overall supply chain costs, flexibility
Product strategy	minimize cost, maximize profit	consider product life cycle costs

Though characterising products as functional or innovative may be an oversimplification, it is a practical high-level classification. In our view, functional products tend to satisfy basic needs which do not change much over time, e.g., staples. Consequently, such products have stable, predictable demand and long life cycles. It follows that their processes do not change much over time, and they focus on eco-efficiency through optimal resource usage and low waste in order to maximize economic performance. On the other hand, innovative products tend to satisfy fast-changing needs. As such, innovative products have unpredictable demand and short life cycles, e.g., hand phones. What makes a product innovative is the drive towards green efficiency through the application of specialised processes with the aim of keeping up-to-date with emerging environmental legislation. Hence, innovative products and green efficiency are highly related. Table 3 summarises our views on functional and innovative products.

Table 3: An analysis of functional versus innovative product characteristics

Characteristic	*Functional*	*Innovative*
Demand	predictable demand	unpredictable demand
Product life cycle	usually long, e.g., more than 2 years	usually short, 3 months to 1 year
Product variety	low (5 to 20 variants)	very high (thousands of variants)
Process	low-tech processes, cost efficient	high-tech processes, green efficient

From the above analysis, there are eight (2 x 2 x 2) possible theoretical strategy types. However, some of them are highly unlikely or even non-viable in real-world green supply chains. For instance, an innovative product matches with a green efficiency focused process due to its primary focus on environmental efficiency, while a functional product matches with an eco-efficient process due its focus on minimizing costs. This analysis is summarised in Figure 1. Hence it is worthwhile simplifying our taxonomic scheme into two dimensions: either relationship and product type, or relationship and process. In the following section we further deliberate on the taxonomic framework for selecting appropriate green supply chain strategies.

Product \ Process	**Eco-efficiency**	**Green efficiency**
Functional	Lean-based strategies	(Mismatch)
Innovative	(Mismatch)	Innovation-centred strategies

Figure 1: Product-Process characteristics and green strategies

5. Taxonomic Selection of Green Supply Chain Strategies

Based on the two basic dimensions that influence strategic green GSCM, supply chain managers can use a matrix to determine the best green strategy. Figure 2 shows the resulting 2 x 2 matrix which characterises the relationship-product characteristics that influence the choice of green strategies. The horizontal axis shows product characteristics defined in terms of the level of innovation. Innovativeness, defined in terms of the number of innovative changes per period, is used to position products on the horizontal axis. On the other hand, the vertical axis reflects the relationship or the level of collaboration in the supply chain of that product.

Relationship \ Product	**Functional**	**Innovative**
Coercive	Compliance-based strategies	Innovation-centred strategies
Collaborative	Lean-based strategies	Closed-loop strategies

Figure 2: Relationship-Product characteristics and green strategies

As outlined in the matrix analysis, there are four feasible generic green supply chain strategies. In cases where a product is functional and the relationship is collaborative, lean strategies, optimal resource usage and low waste can be adopted. In situations where players in the supply chain are collaborative and the level of innovation is high, closed-loop, product take-back, reverse logistics, and remanufacturing strategies are imperative. Where processes are highly innovative with low level of collaboration (coercive), innovation strategies such as green product design are recommended. Finally, in a coercive supply chain environment with minimal inter-organisational engagement and functional product (process), compliance-centred strategies are adopted where concerned industry merely focuses on satisfying stakeholder regulatory requirements. An exact analysis using relationship-process characteristics is shown in Figure 3.

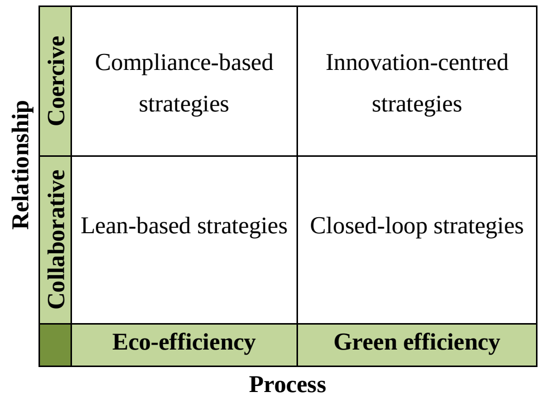

Figure 3: Relationship-Process characteristics and green strategies

Table 4: Relationship-Product characteristics and resulting green strategies

Relationship-Product Characteristics	*Resulting Green Strategies*
Coercive relationship + Functional product	Compliance strategies
Coercive relationship + Innovative product	Innovation strategies
Collaborative relationship + Functional product	Lean strategies
Collaborative relationship + Innovative product	Closed-loop strategies

Similar to the matrix analysis in Figure 2, Table 4 outlines the four suggested solution strategies emerging from the taxonomic framework. In the next section, we deliberate on the four generic green strategies as suggested by the matrix analysis.

5.1 Compliance-centred Strategies

When inter-organisation engagement is minimal and the product and its processes are functional (standard), firms adopt compliant-based strategies merely in response to environmental regulations, stakeholder requirements, and customer pressure. In other words, the nature of supply chain relationship is rather coercive than collaborative. Companies considering the introduction of green strategies in their supply chains commonly adopt these strategies.

Compliance-based strategies include establishment of international standard systems such as ISO 14001 (King et al., 2005), use of performance standards, inclusion of purchasing contracts for suppliers to meet certain regulatory requirements. Similar to basic certification systems is the use of broad statements with purchasing principles or guidelines for suppliers. Most organisations such as DuPont, Wal-Mart and Seventh Generation introduced procurement requirements for compliant purchasing (Shang and Marlow, 2005; Plambeck, 2007). The advantages offered by compliance-centred strategies are as follows:

(i) Environmental performance benefits;
(ii) Use of globally recognised systems, and;
(iii) Third party management of performance.

These aspects in turn, improve recognition and acceptance not only by suppliers, but also by the market and stakeholders. Ambiguity of the desired performance is significantly reduced. The disadvantage of these strategies is that, because if their reactive approach, they offer limited competitive edge due to their lack of innovativeness, a lack of uniqueness, and ease of application by competing supply chains. Since the systems are managed in a climate of low collaboration, they only guarantee compliance with regulatory requirements. As a result, additional benefits from innovation or economic efficiency are very unlikely.

5.2 Lean-based Strategies

Lean strategies are a more recent group of green strategies whose focus is on eco-efficiency in which suppliers are required to satisfy certain operations-based efficiency targets. In addition, secondary environmental performance benefits may be obtained from some operations practices that provide green performance advantages. These strategies are most ideal when the supply chain relationship is more collaborative and the process/product is still functional. A high level of inter-organisational collaboration, arising from the use of integrative inter-firm performance requirements, is necessary for situations with complex problems associated with waste reduction and recycling (Klassen and Vachon, 2003). The lean-based strategies link environmental performance with operational efficiency within the supply chain, allowing for the extension of performance requirements into the supply chain that maximises economic performance and enhance environmental performance due to reduced waste and resource usage. Wal-Mart introduced green strategies in order to create zero waste and to sell products that sustain Wal-Mart's resources and the environment (Plambeck, 2007).

The advantages of lean-based strategies are: (i) they offer eco-efficiency to the entire supply chain and (ii) they readily lend themselves to existing organisation goals of optimisation and cost reduction. On the other hand, lean-based strategies do not give room for advanced environmental management initiatives such as green product design, innovation and material substitution. In so doing, the lean strategy is considered as technically weak.

5.3 Innovation-centred Strategies

Innovation-centred strategies focus on developing specialised technologies, product designs, processes and strict green performance standards in order to keep up-to-date with changes in environmental regulations. The point of departure for the innovation-centred strategies from the lean-based strategies is the focus on more environmentally specific performance strategy. In other words, the main investment focus of the supply chain is in complex performance standards for suppliers, and specialised processes and technologies. Thus, the shift from lean to innovation-based strategies with higher levels of innovation and environmental performance requires specialised environmental resources and specialised personnel in order to keep abreast with changes in environmental legislative agreements (Lenox and King, 2004). At product level, resources are needed to build environmental innovative designs into product design and development, product characteristics and functionalities. At process level, resources are used to build environmentally sound production systems and processes essential for innovative green production and distribution. Case examples in this category include Taiwanese information industries whose focus is mainly in product/process innovation and eco-design in order to comply with emerging environmental directives from regulatory bodies (Hu and Hsu, 2006; Ninlawan, 2010).

The advantage of innovation-based strategies is in their ability to offer competitive advantages in a fast-changing environment with ever-changing environmental legislation. However, keeping up-to-date with environmental legislation changes may offer huge challenges due to the need to shift to a collaborative inter-firm relationship. The level of information exchange and relational integration tends to be more complex. As environmental legislation continues to tighten, stakeholders in the supply chain may call for recovery of materials for re-manufacturing or reuse (Kocabasoglu et al., 2007).

5.4 Closed-loop Strategies

Closed loop strategies call for the highest level of inter-firm collaborative relationship over the whole supply chain, with appreciable levels of innovation. Companies adopting these strategies are able not only to keep abreast with complex requirements of the closed-loop supply chain but also to follow a pro-active approach through active and integrative relationships with suppliers from design phase to product take-back. Closing the loop basically involves the capture and recovery of materials for remanufacture and/or recycling (Vlachos et al., 2007). Recovered materials arise from returned, post-use, or end-of-life goods. Thus, closed loop strategies tend to integrate environmental performance to the entire supply chain. Supply chains that endeavour to implement closed-loop strategies certainly need high ability to control the reverse logistics of used materials. Well-known case examples falling in this category are Hewlett Packard's return of printer cartridges, Kodak's take-back and remanufacture of its disposable cameras, and various auto industries' end-of-life vehicle requirements (Guide and Wassenhove, 2002).

One main advantage of closed loop strategies is in their endeavour to seamlessly integrate economic, operational and environmental performance. In this regard, closed loop supply chains tend to incorporate all the advantages offered by the three categories of strategies outlined above. The disadvantages of the closed-loop supply chain strategies include: (i) socially complex relationships which involve complex processes such as product take-back, reverse logistics, reuse, recycling, or remanufacturing, (ii) the lack of readily available infrastructure for 'closing the loop', and (iii) the general disbelief that its implementation is economically viable.

6. Impact of green strategies on operations policies

The above study highlights the fact that specific green strategies affect various aspects of supply chain operations including the purchase of materials and energy, new process technologies, process control involving disposal operations as well as water and air pollution, and output of green and clean products. In retrospect, each strategy has specific impacts on purchasing, product technology, process technology, and logistics and transportation activities, as well as performance measurement systems.

6.1 Impacts of compliance-centred strategy

As the strategy in this category is to comply with stakeholders' requirements, organisations tend to react to changes in regulatory requirements. As a result, purchasing policies should be focused on avoiding the use of hazardous materials through development of material selection criteria. Production processes are often forced to introduce ad hoc solutions in a bid to adapt to new environmental requirements, which may be costly in the long run. Not many changes are expected logistics and transport operations. Basic environmental performance standards such as ISO14000 are adequate enough for this strategy.

6.2 Impact of innovation-centred strategy on operations

In this strategy, managers should give special attention to developing strict performance standards for suppliers of materials and specialised process technologies. Procurement policies should be supported adequately with performance management systems that cater for stringent measures for procurement control. Specialised skills are needed to enhance innovative product development in order to keep abreast with fast-changing environmental regulations. Investment into production process technologies may pose a great challenge in a dynamic innovative environment as managers seek to maintain their competitive position in product and process innovation. Thus, the innovation-centred strategy requires huge investments in R&D and product and process technologies.

6.3 Impact of lean-based strategy on operations

Since the focus of the strategy is to minimise costs and waste, this may require a managerial paradigm shift from individualistic attitude to a more cooperative approach. The expected outcome is a developed ecological network that minimize waste, for instance, one supply chain player may utilize waste output from another player. Management may need to consider investing in new process technologies that minimize waste and improve on production efficiency.

6.4 Impact of closed-loop strategy on operations

Significant changes are highly expected regarding operations policies as the supply chain players seek to gain a competitive advantage. Procurement policies are to be changed through collaborative relationships. Supply chain value partners have to collaborate in establishing research and development (R&D) projects that carry out product life-cycle analysis aimed at introducing new product and process technology innovations so as to contribute to the overall value creation. As far as production processes are concerned, organisations do not only seek to green efficiency from an ecological perspective, but also to take advantage of the green strategy to gain a competitive position. New green products that can be remanufactured or recycled are expected. As a result, management should pay attention to developing relationships between supply chain operations. As far as logistics is concerned, recycling and product take back initiatives are a priority. Therefore, logistics operations should be redesigned to suit such integrative relationships between players.

7. Conclusions

The selection of the most appropriate green strategy and the insight of the implications of the chosen strategy is a challenge to most decision makers in GSCM. Supply chain managers should be able to identify the most appropriate green solution to meet various needs of different product-market characteristics. Moreover, the decision makers should find ways to evaluate the impact of potential supply chain strategies to the natural environment and the environmental performance change, apart from the economic advantages expected from the strategy. In this study, we have proposed a taxonomic approach to the selection of appropriate green supply chain strategies, based on a study of real-world case studies found in literature. The study identifies three key dimensions upon which our taxonomy is based, that is, *product*, *process*, and supply chain *relationship* or *collaboration*. Unlike previous taxonomies that focused on the nature of the product and its life cycle, this study suggests the use of relationship and process/product variability metrics. Our approach categorises green supply chain strategies into compliance-based, eco-efficient, innovation-centred, and closed-loop strategies, proving case examples in each category.

This research offers a significant contribution to both academics and practitioners in green supply chain management. First, the study goes a long way in providing a practical tool or framework for managers when developing green supply chain strategies, given specific industrial contexts in which the strategies are to be applied. Second, the taxonomic framework offers managerial insight into the implications of the choice of specific strategies on the operations policies of the supply chain. Third, the study goes a long way in advancing the body of knowledge in GSCM.

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